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ABSTRACT

The major advantages in computer-assisted instruction (CAI) are the potential for the individualization of instruction and the savings in instructional time. CAI's major disadvantages include the large amount of time required for course development, personnel required, initial outlay of funds, and the total cost. Other disadvantages, due to the present state of the art, are the small amount of software readily available and the short supply of personnel able to develop CAI programs. The three main methods of programing, in order of complexity, are linear, branching, and multi-track. These methods are explained briefly as preface to a case study of CAI courses at the U.S. Naval Academy. Procedures for course development, course revision, course conduct, and course evaluation are reviewed. Recommendations for personnel and time resources, as a result of the Naval Academy experience, are set forth. (JK)

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Computer Assisted Instruction:
A General Discussion and Case Study

AUGUST 1971

U.S. Civil Service Commission
Training Assistance Division,
Bureau of Training

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INTRODUCTION

Computer assisted instruction is an instructional method which uses the computer as an integral part of instruction. The computer acts as an instructor, presenting the material, asking questions to check comprehension, presenting more material and testing.

Since it is a new instructional and experimental method, CAI is being used to a limited extent by the Federal Government. As is often the case with new instructional methods, trainers tend to overreact in one direction or the other; some think CAI is the solution to all training and education problems while others think it will never be practical and effective and therefore should not be used. Neither of these attitudes is valid; the value of CAI lies between these extremes.

Very few training specialists know much about CAI: it is therefore difficult for them to make a rational decision about the appropriateness of it for a particular situation. It is not enough to know that CAI worked for someone else, the conditions under which it worked must be known. It is not enough to say that CAI *in general* is effective and efficient, it is only effective under certain conditions. Although the ideal conditions for CAI are not yet known, several institutions who have used CAI have some idea what these conditions are. The purpose of this paper is to give a general discussion of CAI and to focus on the U.S. Naval Academy's specific experiences in this area.

In the absence of specific knowledge of the effectiveness of CAI, what criteria can the Federal trainer employ when considering the use of CAI? In this paper, the following points, among others, must be considered: the availability of appropriate resources, the type of subject matter, the importance of the need for individualization and the number of students. This pamphlet is designed to provide training specialists with a discussion of these considerations so that they can make a more meaningful decision in relation to CAI.

Since PI is an integral part of CAI, an understanding of PI is useful. For those who do not already have this knowledge, a review of a previous pamphlet in this series, (*Programmed Instruction: A Brief of its Development and Current Status*), is advisable.

The following five cautions should be kept in mind as this pamphlet is read:

1. Don't act as if computer-based training were something entirely new. Always conceive of computer-based training in such a way that you can relate it to what is known about conditions for effective training.
2. Don't be misled into thinking that a computer offers a training system which is obviously so superior that no evaluation need be made or records kept.
3. Don't just apply the computer to training. Carefully analyze the total training process and apply the computer to those functions that need automation.
4. Don't be seduced by claims that, almost mysteriously, profound learning and understanding occurs when a trainee "uses a computer to interact heuristically with the subject-matter." Systematic practice with feedback is still the best condition for learning.
5. Don't put all of your "eggs" in any one type of research and development "basket". Because of high investment costs and other factors, there seems to be a somewhat unhealthy emphasis on an immediate capability.[1]

See footnotes at end.

COMPUTER ASSISTED INSTRUCTION

Computers may be used in many ways in the educational process: in administration, testing, record keeping, simulation and computer assisted instruction.

. . . many people use the term "computer-assisted instruction" . . . to cover a wide variety of different conditions. Careful reading often is required to determine whether, by "computer-assisted instruction," the author means: (1) Administrators using computers to store and process administrative data about students, (2) students using computers to solve problems, e.g. mathematics, (3) students using computers which represent complex relationships, e.g. math, physics, chemistry labs, etc., (4) a computer presenting linear-type programmed instruction, or (5) computers in highly individualized and interactive tutorial instruction.

Frequently, the involvement of a computer in the instructional process seems to blind one to many of the more significant functional properties of that instructional system. Those functional properties are the more important characteristics, not that a computer is or is not involved.[2]

The first four of these functions use computers solely to facilitate the eductional process; while this is a use of computers *in* eduction, it is not a use of computers to educate. The last category, computer assisted instruction or CAI, uses the computer as an intrinsic part of the learning process. In CAI the computer is used for individualizing instruction.

Computer assisted instruction (CAI) is a relatively new instructional method which uses the computer in conjunction with programmed instruction (PI). As is true of any other instructional method, CAI is not a cure-all for instructional problems; it must be used only when it is appropriate.

For some of us, it has become illogical to attempt to solve problems in educational strategy by *one* medium alone, whether it be film, television, or language laboratories, although some of these media are almost systems in themselves. The systems view of media holds that the digital computer, no matter what its performance characteristics may be, is just another important component of a larger assemblage of instrumentation needed to implement favorable conditions for learning.[3]

See footnotes at end.

Like any other instructional method it has its advantages and disadvantages, is appropriate for some situations and not others. Since CAI is based on PI, it has some of the same advantages and disadvantages. ". . . CAI in its most primative sense is merely PI with a sort of electronic page turning."[4]

PI is an instructional method in "which the student is lead through a series of questions, responses, and confirmation of his responses until little by little he has progressed from small bits of relatively simple knowledge to more complex principles.

Many writers have noted the similarity between the PI approach and the tutorial system which asks selective probing questions of a student, and then lets him do the work of learning. The tutor must know his objective and dissect the subject matter into small bits of information. Through a logical progression of elementary questions and answers and through reward or correction of answers, the tutor brings the students to a grasp of the whole concept. Thus the procedure may be likened to the building of a picture puzzle where the complete configuration comes only through the correct placement of individual parts.[5]

The computer can be programmed to adapt the learning situation to each individual's learning difficulties which would burden an instructor with many trainees. Thus a student can progress at his own rate. The computer allows for true individualization of learning. In some cases the computer presents the learning material to the student by means of a cathode-ray tube (CRT), a television-like screen. A question is then asked of the student. If the trainee responds correctly, he is directed to the next bit of information. If he answers incorrectly, he is directed to a bit of material which is specifically designed to remedy the particular type of mistake which the student made. If the student still does not learn, he is again given additional information. The student then is presented the next bit of information. This whole procedure is done automatically; the student is not required to flip pages or turn the book upside down to check his answer. The computer can also provide individualized homework assignments based on specific deficiencies.

Advantages and Disadvantages of CAI Over Other Instructional Methods

There are certain advantages to using CAI rather than some other instructional method. The major ones are the potential for individualization of instruction and the savings in instructional time. The major disadvantages of CAI include the large amount of time required for course development, personnel required, initial outlay of funds and the total costs.

Advantages of CAI

Individualization of Instruction

CAI has practically unlimited possibilities for individualization of instruction, while PI has the potential for a very limited amount of individualization of instruction.

> The true individualization of instruction is possible and represents the real departure of CAI from programmed instruction. Thus, while programmed instruction provided the initial break in thinking about individualized instruction and some useful functions, CAI provides the means by which we can put that thinking to work, and add new functions, the problem is how to adjust the fabric of instruction to the form of the students' aptitudes, a personality and beginning knowledge—the texture of his entry behavior. Basically we are dealing with a problem of adaptive instruction. By that we mean that the instruction must depend on knowledge of the student.[6]

Although the computer is limited in that it can store only a certain amount of information, this is generally adequate. The only real limitation is the ability of the author.

In PI, the next bit of information which is given a student is determined only by the answer he gave to the preceding question. In CAI, the next information given depends not only on the responses made to the previous question, but on either all or many previous responses. If the student had difficulty with a certain type of learning process, regardless of subject matter, a good computer program is capable of emphasizing the modules in which the process occurs, as well as reinforcing individual modules by providing additional materials.

Savings in Instructional Time

Another major advantage of CAI is that is generally requires less time than traditional methods to teach the same amount of material. "One of the most consistent findings with CAI tutorial applications is marked savings in instructional time with no loss in post-instructional achievement performance."[7] The U.S. Army Signal Center and School reports the following in their feasibility study of CAI:

- Based on the criterion measure there was no significant difference between instructional methods. Significant differences were found in performance among students of different aptitude levels.
- The mean time required to complete the CAI course was about 11 percent less time than the fixed time for instructor-controlled and television-controlled instruction when all aptitude levels were included. High level students averaged 49 percent faster, medium level students averaged 17 percent faster, and low-level students averaged 32 percent slower than those taught by conventional methods.[8]

One year later, a similar study was conducted by USASC,[9] and it was found that, due to course revisions, the mean amount of time to complete the CAI course was decreased by an additional 9 percent, for a total of 20 percent less time to complete a CAI course than the teacher-administered course (TAI).

Human Resources Research Organization (HumRRO), which is developing a model CAI system, states the following about the efficiency of CAI versus TAI:

> Thus, the most plausible assumption would seem to be that, at worst, PI and/or CAI will be no better than the *average* textbook or the *average* lecture notes taken from the *average* lecturer. We might next ask how conservative an assumption of equal effectiveness might be. In assessing the degree of conservatism it will be well to recall the analogy proposed at the outset of this paper. Before 1910 the airplane and the horse drawn buggy might have been equated in their effectiveness as transportation. Up to perhaps 1950 equal effectiveness debates might have been carried on about airlines and railroads. Today the matter is clearly beyond debate. Since CAI is still in a very early stage of development, it is reasonable to expect ever-increasing effectiveness with its continuing evolution.

The point is well-illustrated by two studies. In the first study. ["Fixed Sequence Versus Branching Auto-Instructional Methods," *J. Educ. Psy-*

chol., vol. 52, 1961, pp. 166–172] Silberman *et al.* were unable to demonstrate advantages for a branching presentation via CAI where the criterion for branching was error rate. In the second study, ["Effects of Branching in Computer Controlled Auto-Instructional Device," *J. Appl. Psychol.*, vol. 46, 1962, pp. 389–392] Coulson *et al.* were able to demonstrate these advantages after revision and refinement of the instructional program and decision criteria were effected. "In the accumulation of many small improvements and sharpening of techniques, the inherent potential of CAI is likely to be realized in time. Thus, the assumption of equal effectiveness is a conservative one which almost certainly will become more so as time progresses." [10]

Other Advantages of CAI are secondary and mainly a matter of convenience. The four which will be discussed are: safety and expediency of instruction, record keeping ability, increased instructor effectiveness, and increased quality of training. The individualization of learning itself could, under the right circumstances, justify CAI, although the other uses of the computer help make CAI more cost-effective than the individualization of instruction alone.

The computer can be very useful for dangerous, lengthy, or expensive-failure learning situations. Laboratory experiments can be very dangerous, but with the computer, the dangers of explosions, fires, et cetera, are eliminated. Thus the student can still check color, temperature, and chemical reactions, but without any of the danger usually involved. The time required for many experiments in biology can be greatly shortened with the use of the computer. Men learning to fly use a Link Trainer, a simple computer which simulates all the important aspects of instrument flying.

The computer has the capabilities of keeping an automatic record of all student responses. In this way, not only can individual trainee performance be noted, but the strengths and weaknesses of the course can be noted. The trainees also have the option of commenting on any question which they do not understand, or an answer with which they do not agree. If many of these comments are made on any particular question, either the question or the module need revision. This is an improvement over traditional instruction since learning difficulties can be pinpointed to a particular module. This facilitates revision since incorrect answers can be directly associated with a particular unlearned module.

CAI does not eliminate the need for instructors, it merely puts the emphasis of an instructor's role in a different light. The instructor has fewer traditional demands on his time since he has a lighter teaching load and uses less time to evaluate trainee learning. He does not need to spend time maintaining records. As a result, he has more time to spend with the unique problems of each individual. Since the instructor is relieved of the tedious work, his time can be more creatively and effectively spent.

The quality of training can be increased, since it is possible through CAI for all students to have an equally good instructor. In traditional learning, some instructors are better than others, while in CAI, the best instructor can be chosen. Since so many trainees can use one course presented by the same instructor, it is important that he be effective. In traditional classrooms, the influence of any one instructor is limited, while in CAI it can be extremely extensive.

Disadvantages of CAI

The disadvantages of CAI can be put into two categories, those which are a result of the state of the art of CAI, and those inherent in CAI itself.

State of the Art Disadvantages

Software

The former includes mainly the software portion of the CAI system. Unfortunately, problems surrounding software are often overlooked when CAI is being considered as an instructional method. Very few programs are available for off-the-shelf purchase, which is not usually mentioned by hardware salesmen. Two authors stress this in their discussions of CAI:

> The press implies that the heavy investments of Wall Street and of giant new industries have rounded up the brains of the nation, have produced quality programs in quantity, and are ready to move with dispatch into the schools. It was a real shock to discover how crude and primitive the programs actually are, and how far they are from the large-scale integration into the schools or into the educative process in general.[11]

In the field of computer design the most severe lack of knowledge is not how to design and build bigger and faster machines, but how to make them function, how to integrate them into the human world, and how to make them do what we want them to do. Norbert Wiener's later writing harped upon the danger we risk by building machines to perform functions that we do not adequately understand. The dangers are real because of our ability to understand the purpose to which they might be put; and we could end by putting electronic machines to uses we would not want to put them . . . we really understood what the uses were.[12]

It is known by people who work in the field that CAI is not appropriate for all types of subject matters; unfortunately which type of subject matters are most appropriate is not known. This was not always considered when existing courses were developed. Some of the CAI courses which have been developed would have been more effective with some other instructional method. This, in addition to the small amount of software available, greatly limits the number of effective CAI programs available.

Extensive research still needs to address this question. We believe, however, that at the present state of the art of producing CAI materials, certain types of strategies, and obviously that subject matter which is seemingly dependent on those strategies for effective presentation, are overly ambitious. Thus, our experience, would lead us to avoid the initial presentation of concepts (total tutorial approach) for college level subject matter of some complexity. Similarly, we would avoid relating the system to mechanical page turning employment, whereby large amounts of text are presented without any attempt at periodic evaluation of individual progress. Well structured, tutorial exposition is reasonably undertaken for upper level course materials. Review, drill, simulation, gaming, and evaluation for most disciplines are also within the realm of economic attainment.[13]

Personnel

Since software is generally not available for purchase, it must be developed in-house or by a contractor. Individuals possessing this skill are seldom available in-house to a Federal agency. "It is unlikely that classroom teachers or school systems will be more able to prepare computer programs in the future than they have been able to write textbooks in the past." [14] This statement applies to Federal trainers as well. No one individual combines all the capabilities necessary for the development of programs; a team of individuals is required consisting of: author, instructional programmer, audiovisual expert and behavioral scientist, among others. The U.S. Army Signal Center and School lists certain individuals as those necessary as the basis of a USACSC CAI project team (see fig. 1).[15] The same personnel would be required for any CAI project, but the numbers of some of the types of individuals may vary depending on the number of courses in CAI being used. It is obvious that no one person can fill all these roles. Often these different types of individuals are not on the staff and must be recruited on a full or part-time basis.

Inherent Disadvantages

The inherent disadvantages of CAI cover such things as cost, time, initial outlay as well as other practical considerations.

Cost

Although the cost of CAI is very high when compared with other instructional methods, CAI can be made cost-effective. The cost of a CAI course is much greater than a course developed in another instructional method. CAI course development requires several times as much time as TAI courses. Most Federal training courses use little hardware; thus the cost of the hardware in CAI is much greater than that in TAI.

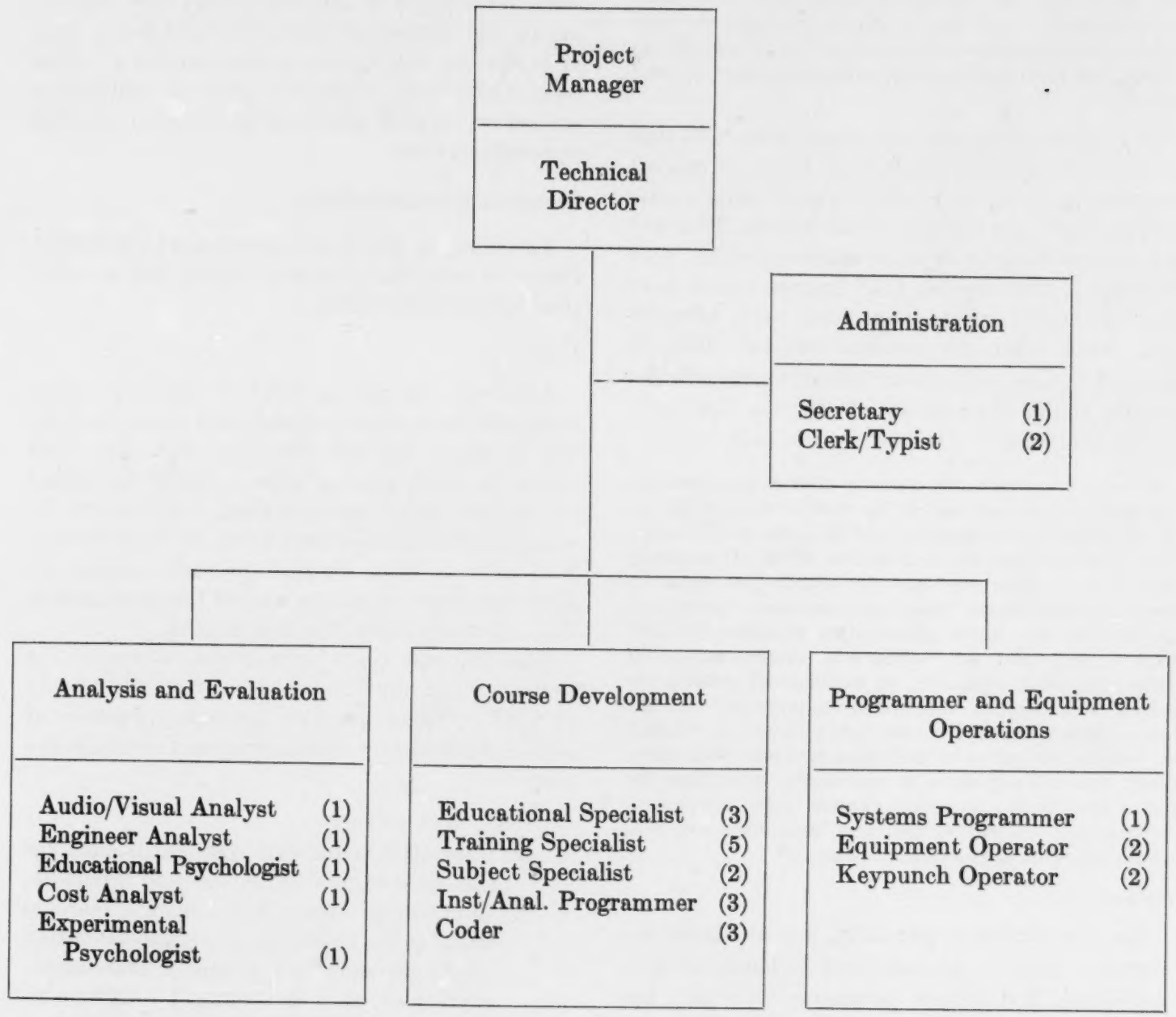
The different costs were broken down by the Continental Army Command in a feasibility study of CAI.[16] There are two general categories of costs, CAI systems costs and program development costs.

I. CAI Systems Costs
   - A. Capital development costs—this includes the hardware, installation and facilities.
   - B. Continuing costs—this category includes those costs which require periodic outlay of funds such as: system maintenance; operations, such as cooling, humidity control, and electricity; program adaptation and maintenance—which requires personnel and materials to update and modify courses; overhead and supplies.

II. Program Development Costs
   - A. Course material preparation.
   - B. Course implementation and debugging (categories A and B include the salaries of programmers, coders, analysts).

FIGURE 1

USASCS CAI MANPOWER SUMMARY



C. Training aids.
D. Overhead.

CAI courses differ from other instructional methods in that a large amount of money is required initially to purchase the hardware. In other types of courses, audiovisual equipment can be obtained piece-by-piece as funds allow, while in CAI courses, a large amount of money must be spent even before the course is developed. This would be difficult for agencies who get training funds on a yearly basis and would have to spend all 1 year's training money on a CAI system in the first few months of the year.

There are two seemingly conflicting opinions about the cost competitiveness of CAI: "So, eventually, the cost/benefits issue must be faced. The

comparison is inevitable. And for the moment, at the public school level, that comparison cannot help but be unfavorable for CAI."[17] Another opinion asserts that: "This illustrates the general principle that savings in instructional time obtainable with CAI will more than offset the additional costs of the CAI equipment and lead to a net reduction in total training costs per course graduate."[18] It is true that many CAI courses are not presently cost-effective; however, as trainers become more knowledgeable in this instructional method, the cost of CAI should compete favorably with TAI. The second quotation, above, refers to a purchased computer system used for 18 instructional hours a day, 5 days a week, with 24 student terminals. With fewer terminals or instructional hours on the computer, a CAI system would not be cost-effective. The important factor is the amount of time the computer is used. Unless it is used to the maximum it will not be efficient. During the developmental stages of a system, the stress is put on making it effective. Later, when it has been proven effective, the efficiency as well as other practical aspects are improved. CAI is still in the developmental stages and so is not as efficient as it will be in the future. Although it is difficult to make CAI cost-effective under present conditions, in the future this may change. "Given the above set of assumptions along with the reasonable notion of at least equal effectiveness for CAI and TAI, it is predicted that, less than 10 years from now, CAI costs—including the development expense of a number of (600) courses—will be roughly half the cost of comparable TAI."[19]

It is difficult to predict how much the software development will cost, but the hardware costs are quite standard.

Let's consider what experience to date has shown to be the requirements of large scale CAI centers for annual funding levels. From informal discussions with knowledgeable persons regarding their CAI projects' fiscal problems, it appears both internationally and in the United States that an operating budget of approximately $250,000 to $300,000 a year is necessary merely to maintain facilities in operation. The reason for this becomes quite clear if one considers simply the rental price of an IBM 1500 system as an example. The hardware alone averages $100,000 to $110,000 per year.[20]

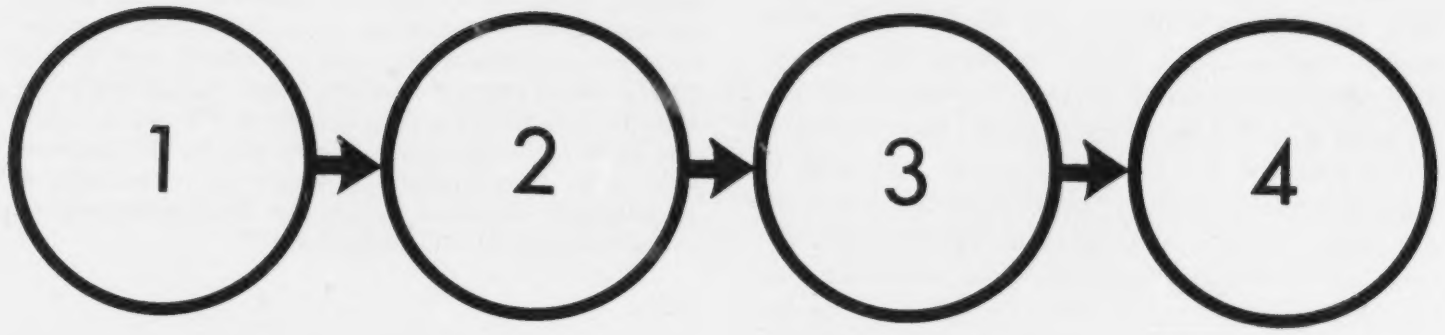
Time

CAI courses represent an enormous investment of time. The U.S. Naval Academy reports using between 45 and 350 hours of author time per CAI instructional hour and between 120–625 hours of programming time per CAI hour. Different variables affect the amount of time necessary to develop and program a course.

Since CAI is a new field, it takes more time at present to develop a CAI course than it will in the future. Each author will not have to learn for himself how to avoid lengthy mistakes since guidelines will be available to him. But because of the nature of CAI, course development will always be considerably more lengthy than traditional course development. The time used for course development will always be a disadvantage, but will become less so with experience.

There are other inherent disadvantages of CAI which apply particularly to Federal government and industry rather than the school system: (1) CAI is only practical if a large number of trainees will be using the course; it is not economical to develop for only a few; (2) the subject matter must be of a relatively stable nature or it will not be economical because of the changes which will be constantly necessary.

THE LINEAR PROGRAM [21]

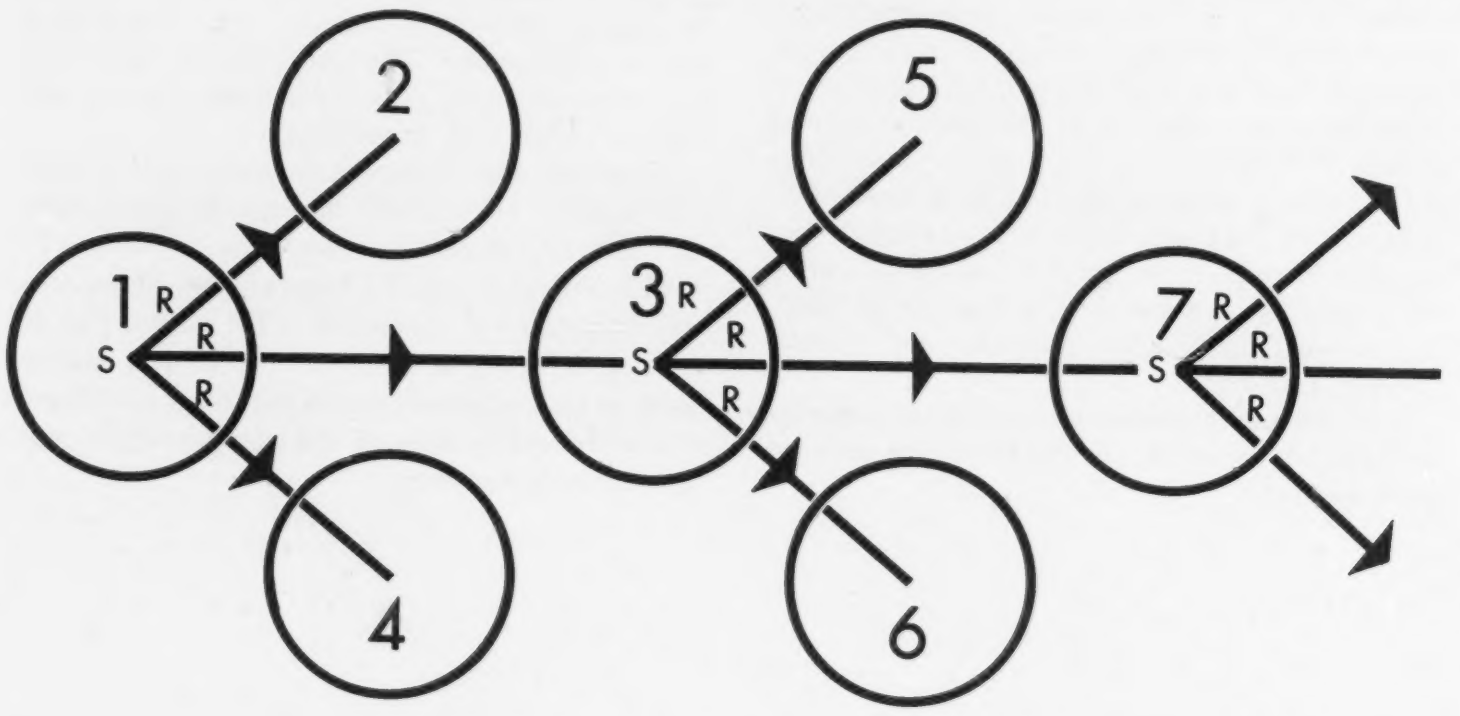


Programming Methods

The three main methods of programming, whether for PI or CAI, and in order of complexity, are linear, branching and multi-track. In the linear method, the trainee is presented with a bit of material and is asked a question about it. After he answers, he is told whether or not his response is correct, he then proceeds to the next bit of information.

The branching program is similar to the linear except at the point when the trainee gives his response. If the response is correct, he moves on to the next bit of information. If it is incorrect, he is given some remedial instruction designed to correct his error. A different type of remedial instruction is designed for each incorrect response.

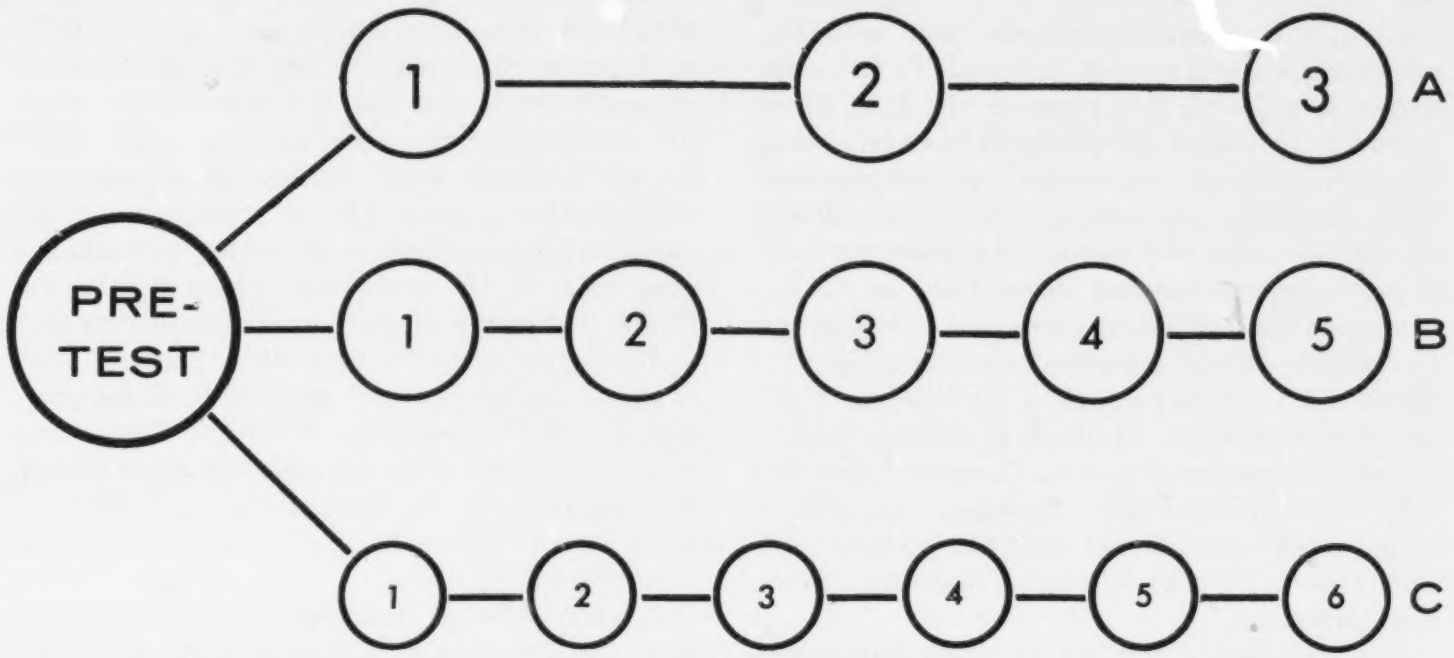
THE BRANCHING PROGRAM [22]



THE MULTI-TRACK PROGRAM [23]

The Multi-Track Program

This type of program is different than the two other types as can be seen by the following diagram.



Several different versions of the same course are developed for different levels of trainees. A pretest is given and the trainees are placed according to the results. The same material is presented but with varying step sizes. "A superior student will be able to use a relatively short program with fairly large steps enabling him to remain interested in the material. A poorer student will be led through the same information in a longer program with very small steps in order to minimize his misunderstanding or 'getting lost' in the program." [24] This type of program would be very cumbersome if it were in text form (or on a teaching machine) while the computer can handle it easily. The branching and multi-track programs take advantage of the computer's capabilities for the development of highly individualized instruction.

The most effective use of the computer, however, is when multi-track is combined with branching. In this case, the student works at his own level; he is given remedial instruction according to the type of error made when he responds to a question. Additionally, with the computer, the type remediation and the next bit of information given is determined by the student's total previous responses.

So far a general introduction to CAI has been presented; some advantages and disadvantages have been outlined. The next section will describe a case study of an actual application from its development to its current status.

CAI AT THE U.S. NAVAL ACADEMY

"The amount of knowledge needed by junior naval officers, like many of their civilian peers, has increased exponentially in the past decade. Conventional teaching methods have been tremendously pressed to meet this need. To find some means of relieving this pressure, the U.S. Naval Academy and other Navy schools have tried such 'non-conventional' techniques as programmed texts, language laboratories, educational closed-circuit television, and the like. An emerging technique—computer-assisted instruction, or CAI—was made the subbject of a two-part investigation to determine its effectiveness in midshipman education." [25] The first part, the CAI-Teletype Project, utilized teletype terminals to access a remote, commercial computer system. The second part, the CAI–1500 Project which is discussed here, utilized a dedicated instructional computer system (the IBM 1500/1800) with 25 remote, multi-media student terminals.

The application of CAI in other institutions was studied to determine its effectiveness. From the findings obtained, it seemed that the Naval Academy could alleviate the above problem through the use of CAI. The following capabilities of CAI can make instruction more effective:

> "The computer offers a 'management system' that can incorporate all instructional media—such as programmed texts, films, television, and simulators.
>
> "Students will receive individualized instruction.
>
> "Courses can be taught in greater depth.
>
> "Courses could contain more material if taught in the same length of time as traditional courses, or
>
> "Length of individual course could be shortened and time used for other military training.
>
> "Subject matter will be effectively presented via the most appropriate instructional media.
>
> "Course designers will be aided in determining optimum course content." [26]

Course Description

The Naval Academy began its extensive contact with CAI, in the fall of 1966, with seminars on the subject by the Office of Naval Research and General Learning Corp. The Academic Computing Center was responsible initially for coordination of the activities and plans for the CAI–1500 Project begun in the spring of 1967. The instructional computer system was installed that summer, when the writing and the programming began. During the academic year 1967–68 the courses were developed and revised. After the completion of the validation phase, which began during the academic year 1968–69, the evaluation phase was begun. Evaluation of the courses has continued into 1971 and is currently in the final steps. (In mid-1969, the group handling CAI and multi-media projects was taken from the Academic Computing Center and formed into a separate organization, designated, first, the Educational and Management Systems Center then, ultimately, the Educational Systems Center.)

The CAI–1500 project began with four courses, two of which were subsequently replaced by two others. The courses presently being run, Modern Physics, General Chemistry, Russian, and Naval Operations analysis, use CAI in different amounts. None of them use it for the total instruction, the total amount of CAI instruction varying from 12 percent to 33 percent per course. The scheduling of the use also varies from course to course, some being at a regularly scheduled time, and one being scheduled according to the subject matter and need. Each course uses CAI in a different way—Russian for drills, listening, and reading comprehension; Chemistry for simulated lab exercises, and problem solving;* and Naval Operations for mock tactical exercises and problem solving.

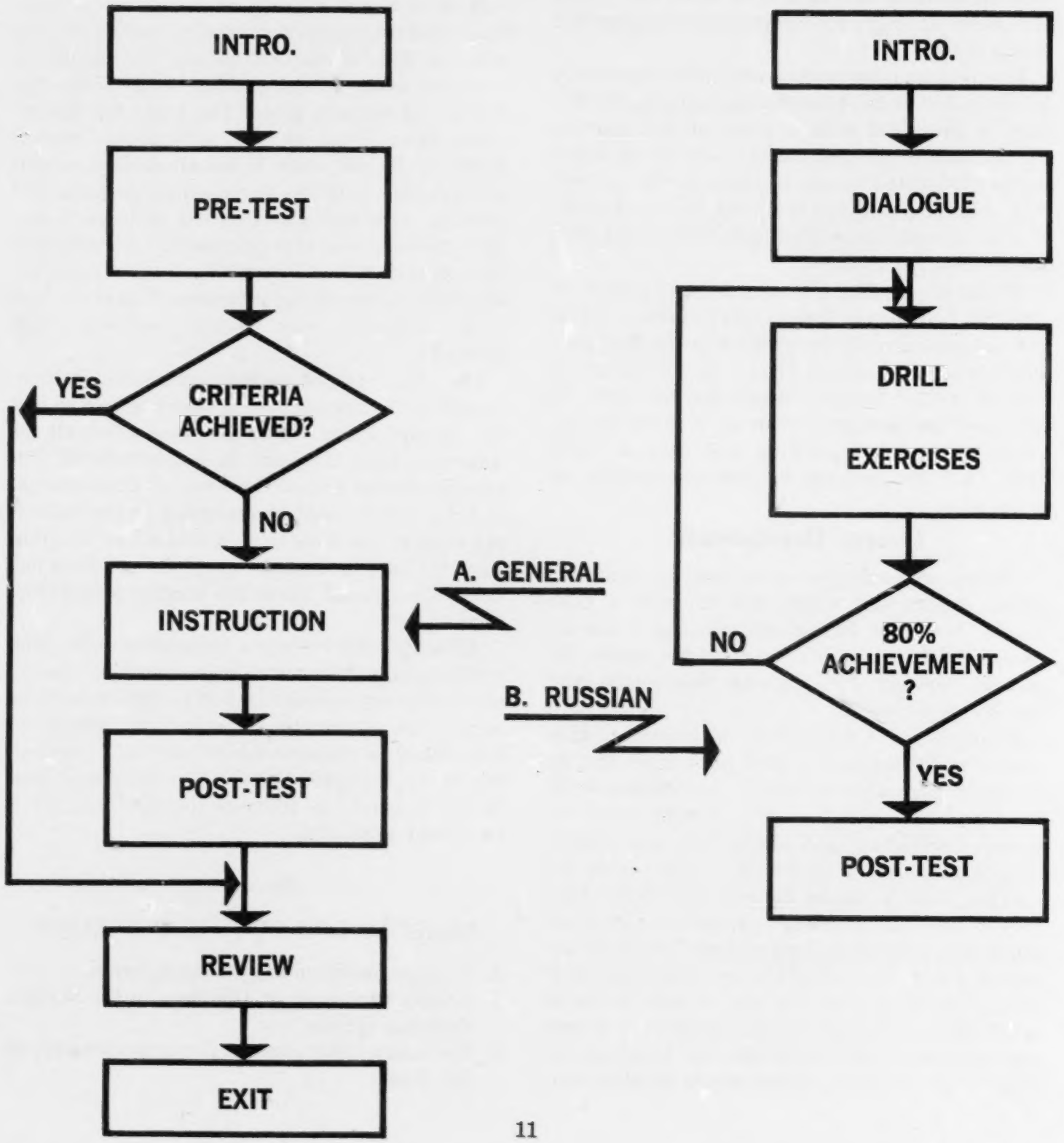
Course Strategy

Each portion of the course which uses CAI is organized in a somewhat similar way, although, overall, a different decision model is now used in each course, particularly Russian (fig. 2). The student is given a pre-test on each portion of material, or module. If he does not achieve the required level for that objective, he must go through the subject matter; if he does, he has the option

*First semester Chemistry is now total tutorial for Gas Laws.

Figure 2.

OVERALL DECISION MODELS



of going on to the next module or of going through this one. After going through the material, the student is tested again to see whether or not he learned the appropriate material. If he did not, remediation is available; if he did, he goes through the module summary and then on to the next module. There are additional aspects and alternatives to this strategy in some courses, but basically it is the same in all. (It is to be noted that this is the course strategy, not the programming method used.)

The programming method used most prevalently is branching. In this type of programming, the student is presented with a piece of information. He is asked a question and the next bit of information presented to him depends on the correctness of his response. If it is correct, it is reinforced; if it is incorrect, he is given remediation and then returned to the question.

Within a module, the student learns a portion of material and then is asked a question on it; if he can answer correctly he goes on to the next portion within the module. If not, he is branched to one of many frames (depending on how he answered the question) where he is given the appropriate remedial learning and then a check test. Then he proceeds to the next portion of material.

Course Development

Course proposals were submitted by each academic department which was to have a CAI course. A specific format was required which included the following: the scope of the course, objectives, project plan, course description and faculty participation.

Seminars on CAI course development were offered in the summer of 1966 but not all faculty members were able to attend. The courses were developed mainly by existing faculty members, several working on each course. Very few restrictions were placed on the faculty in developing the courses. Each developed his own objectives which may or may not have been approved under ideal conditions, but due to lack of time had to be accepted. Each constructed his own finals and midterms instead of using the ones already in use in non-CAI courses. Later in the program, a course development model was established based on experience gained from earlier course development.

Course Revision

It was assumed that course revision would be necessary since CAI was new to most of the instructors. There are two types of revision which are necessary in CAI courses. One type is revision of a particular course or module (formative); the other is revision as a result of experience gained on the hardware.

More extensive revision of the course material than usual was necessary since no course trial was possible. This means that it was not possible to eliminate many of the problem areas before the course was actually given. The input for this revision came from student performance records stored in the computer. When all student records are compiled, it is easy to see which questions and modules were ambiguous or not sufficiently covered. Revision was also necessary to accommodate the different types of learners, which is essential, especially in branching programs. Figure 3 [27] lists some examples why course revisions were necessary.

The other type of revision constitutes "adjustments" to the system, that is, learning how to best use the equipment. These revisions affect all the programs since they are hardware related. For example, it was learned that only a limited amount of information could be presented on the cathode ray tube at one time or it would all be illegible. Also, all but the essential graphics and films had to be discontinued due to the lengthy preparation time of each.

Although the revisions themselves were relatively easy, problems were encountered in the communication between author and programmer. Since courses are so complex, it was often difficult for the author to pinpoint which particular segment was to be changed. Forms were developed later in the progarm to alleviate this problem but it continued regardless.

FIGURE 3

REASONS FOR COURSE REVISIONS

1. Typographical or programming error.
2. Results were poor on this item in the Student Response Matrix.
3. Too many UN's (unanticipated responses), on this item.

4. Help requested by several students on this item.
5. Add review or back-up capability.
6. Additional feedback and/or direction needed as indicated by poor results on the Student Response Matrix.
7. Much EI (extra instruction) given on this item.
8. Other

A number of summer 1970 revisions were made on pre- and post-test items which were not up to standards and were not at appropriate difficulty levels.

Courses which were developed later in the program required less revision than earlier ones. This was partially due to experience with hardware, but also to experience in program design and writing.

Course Conduct

Students are scheduled for the CAI portion of the course just as they are for the non-CAI portions. The students are scheduled for 1 hour at a time and are not permitted to leave before the end (except in the case of the Naval Operations Analysis course, which allows midshipmen to leave at any point in a two-period session that they have completed the problem). Some additional time is available in the evening for those who need it.

The students were given a 15-minute orientation on CAI which was found to be the appropriate amount of time after various trials. A proctor remains in the room to take care of any mechanical problems which arise.

The author of the course, or an instructor, stayed in the room at the beginning of the program, but it was found that the students relied on the instructor too much. Now, the instructor sits in a room off the CAI room and is able to prepare lectures. The Naval Academy found this to be a very effective use of both the instructor's and student's time.

Course Evaluation

The course evalution effort has been divided by the Naval Academy into three portions: (1) the validation phase, or formative analysis; (2) the evaluation phase, or summative analysis; and (3) individual differences analysis. The first consists of determining whether or not the materials help the students achieve the objectives. The second consists of determining how the effectiveness of CAI presentations compares with non-CAI presentations. The third consists of determining how the effectiveness of the course is affected by individual characteristics. This is done separately for each course. Each phase will be discussed separately.

Validation Phase

The validation phase consists of what is usually called testing—testing the students to see whether or not they have learned the required material. There is a difference however, in that the Naval Academy CAI courses use criterion reference testing instead of the standard normative testing. Usually the scores each student obtains on a test are compared with all the others, and the grade he receives is based on his relative position within the class. The Naval Academy project leaders contend that each student's score should be compared with the objectives of the course and his grade determined by how many of these he achieved. It should be noted, however, that this cannot be done if the objectives are not clearly defined.

The validity of the course, this is, whether or not the course accomplished what it set out to do, is determined by the compilation of the student scores. The course requires major revision if a predetermined percent of the students taking the course did not achieve a certain percentage of the criterion tests, in this case 80 percent by 80 percent. The revision continues until this standard has been met.

Preliminary validation began in the spring of 1969. Due to lack of programmers and course development problems, it was not possible to complete this phase until spring 1970.

The tests which were used for the CAI courses were generally new ones developed for CAI. This means that they had not been checked for validity or reliability. This had to be done during the validation phase.

An item analysis was done on all items in the test. This consists of determining how difficult each item is and how well it discriminates between the better students and those who got lower over-all scores. By following this procedure, the quality of the tests can be assured.

Evaluation Phase

"The question typically raised concerning a new technique is: How does the new compare with the old?" [28] This is the area which is covered in the

summative analysis. The evaluation design used is the experimental, or classical, evaluation using control groups and variables.

The achievement of the group using CAI was compared with the achievement of a similar group not using CAI. The groups were controlled on variables such as SAT scores, grade point average and advanced exam scores. By controlling these and other variables, the difference in outcome between the CAI group and the non-CAI group can be directly attributed to the difference in instructional method.

The final evaluation will not be completed until the academic year 1970–71.

Individual Differences Phase

This phase concerns itself with differences in the individual courses, students, and instructors, and how these differences affect the outcome of the course. More specifically, the analyses include:

Module effectiveness
Student attitude
Student correlation
Predictive equations

Module effectiveness

It is necessary to know how effective the individual modules are. This is done by ranking them in terms of the amount of possible gain. They are then ranked in terms of the number of correct answers on the mid-term and final exams. These rank orders are then correlated. This procedure enables the instructor to determine which modules are less effective and therefore need more review.

Student attitude

The change in student attitude over time towards CAI materials was measured. Each module was rated by students in terms of its perceived effectiveness. Also the student's attitude, or perceived effectiveness of the modules, was compared with the achievement on the modules.

Student correlation matrix

Do the students follow similar paths when completing the CAI materials? A student correlation matrix was generated and analyzed to determine whether or not there are any paths which were significantly different at the .05 level.

Predictive equation

Some students learn better using CAI than others; it would be very useful to know which types of students benefit most from CAI. Each of the following characteristics was correlated with the final grade for each student: SAT-Verbal, SAT-Math, English Composition Inventory, Math-Intermediate, Rank in Class, recommendations and activities and others. The appropriate amount of each of these variables was determined in this way, and an equation summarizing the right combination can be developed. The equation will help in the prediction of successful achievement in CAI.

Results and Cost-Effectiveness

At this time, the course evaluation has not yet been completed, therefore no information on results is available. When comparing the effectiveness of instructional methods, cost must be considered as well as the different amounts of gain in achievement. Cost will not be available, however, until the end of the 5-year program. Until then, it is difficult to compare CAI with other instructional methods.

Resources

Personnel

The Naval Academy recommends the use of a team in the development of CAI courses. Developing a program requires several types of skills, all of which are not usually combined in one individual. It requires the ability of a subject matter specialist, an instructional programmer, an audio-visual specialist, and a behavioral scientist. Also required are programmers, systems engineers, and other technical support personnel. The Naval Academy did not have all these skills, so outside help was required.

Authors

Each of the four courses has several authors, or subject matter specialists, who were chosen by the departments involved. None of these had previous CAI experience; therefore it was necessary to give them some instruction in this area. The amount of teaching experience varied from teacher to teacher and between CAI courses.

The authors' teaching load was to have been cut back to allow them time to spend developing the program. Although this was the goal, this was not always possible due to the burden it put on the other instructors' time. Instructors have duties additional to teaching, which also cut into course development time. If the authors had not given some of their own time, the time which was allotted would not have been enough to develop the courses. As a result, the material would have been completed much later. The Educational Systems Center estimates that authors spent more off-duty hours than work time on course development.

In addition to course development, some of the authors did their own programming. Although this was more efficient, because of the author-programmer communications problem, this further reduced the time available for course development.

Programmers

Computer programmers were hired and immediately needed training on the system. The training available to them was inadequate, which resulted in programming delays. It was found that on-the-job training was more successful than formal training so this was given to subsequently hired programmers. The system has four full-time programmers and from three to 10 part-time. The Naval Academy found it difficult to have the appropriate number of programmers available at all times. Although the programmers had slack periods, they often had to work overtime, especially during certain peak periods.

Others

Various other types of personnel were required to maintain the system; some full-time and some part-time. An art staff is necessary to develop graphics and visuals; mechanical support staff and administrative personnel were necessary. Part-time assistance was required in the areas of programming techniques and documentation as well as validation and evaluation. Several system engineers were also required.

Time

An enormous amount of time is required to complete a CAI course. The time mentioned here is only an approximation but will give some idea of how much time to allow.

Author preparation time

> Author preparation time has varied in keeping with such factors as (1) author knowledge of subject matter, (2) author teaching experience, (3) strategy employed for the CAI materials, and (4) subject matter considerations that include level of presentation and degree of conceptualization involved. Accordingly, the Academy has experienced a wide diversity in production time ranging from approximately 350 hours of author time *for 1 hour* of tutorial material in an upper division science course to approximately 45 hours for the evaluation and review design *for 1 hour* of Naval Operations Analysis. Current revision efforts in General Chemistry show that near re-creation of *1 hour's* worth of material requires upwards of 150 hours for all authoring activity.[29]

This means that the instruction must be prepared well ahead of time, and it is not possible for an instructor to prepare a lesson the day before, as is now possible in the traditional lecture method. It was also found that

> five 2-hour blocks of time, for example, are of much less value than two 4-hour blocks. This is because large blocks of time are required to set up, analyze all the points involved in teaching the concept, deciding the best way to present the various parts, and then generating the materials while all this is fresh in their minds.[30]

If the author is to have duties other than CAI development, they should be scheduled around this work to allow long blocks of uninterrupted development time.

Programming Time

Programming time is the time which is required to put the course into the computer. This varied from course to course. Physics required 10,000 hours including revision; Russian, 1,800 hours; Naval Operations, 400 hours; and Chemistry, 2,500 hours. It is difficult to give an average amount of programming time required since this varies according to the complexity of the course.

Other time

The other amount of time which was significant was that which was necessary to develop graphics and filmstrips. Although the actual development time was not lengthy, the turnaround time was 2 months from author to finished product. It was necessary, as a result of these difficulties, to restrict the use of audiovisuals to an absolute minimum.

Hardware

The computer system consists of a central processing unit and 24 student terminals. Each terminal contains a cathode-ray tube (CRT), an image projector for filmstrip, an audio source, especially for the Russian course, and a typewriter. The cathode-ray tube presents the majority of the material and an attached light pen or keyboard is used by the student to respond to it. The majority of the typewriters were later removed since they were used very little and the expense involved in keeping them was unjustifiable.

The Naval Academy reports few equipment failures which were not solved quickly. The computer reliability is estimated at 96–98 percent.

Recommendations

"The following recommendations emanate from our U.S. Naval Academy experience and underscore the suggestions of many other CAI investigators:"

1. Before any course materials are considered or generated, plan each phase of the project. Devote extensive preliminary effort to specifying project goals and student-instructor goals, to mastering system-capabilities, to understanding and appreciating principles of sound pedagogy and precepts of educational technology, and to determining that a systems approach to learning-teaching is necessary, practicable, and attainable in this circumstance.
2. Stress and adhere to the requirement to produce realistic quantities of high quality, that is, effective materials. Realize that creation of packages of excellent CAI materials can no more be produced under deadline production methods than new ideas can be forcibly formulated in stipulated numbers of minutes.
3. Appreciate the fact that the computer is a tool, an instrument which is to serve the needs of students, subject matter, and teacher, rather than vice versa. It should always be subordinate to and supportive of the instructional message. Realize that sophisticated students are unimpressed with the gimmickry of blinking lights, roll-on messages, caricatures, and even with the involvement of personally responding to each question when confronted with instructional messages that are irrelevant, confusing, incomplete, unchallenging, impersonal, et cetera.
4. Ensure that CAI materials receive thorough validation, that is, analysis of content and student performance data to ensure that they are both teaching and testing as designed to do, and that revisions of course materials are based on as clearly objective need as possible to attain.[31]

Conclusions

The following conclusions do not imply any criticism of the Naval Academy; they are mentioned only so that Federal EDO's who are considering using CAI can avoid similar problems. These problems are not unique to the U.S. Naval Academy and would probably occur in most similar situations. The Naval Academy has derived some of these conclusions through their experience with CAI; others have been drawn from similar studies.

1. The time and personnel requirements must be determined before the CAI commitment is made. If adequate resources are not available, the commitment should not be made.
2. The project should be started on a small scale so that experience can be gained before making a large-scale commitment.
3. It is desirable to begin with a course on an already existing computer.
4. A team of individuals must be available for course development.
5. If sufficient time and personnel have been allocated, mediocre or half-good courses should not be accepted.
6. The courses should be developed in such a way that they use the capabilities of the computer to the fullest, that is, individualize instruction to the maximum.
7. It is essential that a pilot study of the course be conducted before the course is used.

SUMMARY

CAI is an instructional method which has the capability of highly individualizing instruction. But it is only one instructional method among many and not appropriate for all learning situations and all types of students. If CAI seems to be the one which will best fit an agency's needs, it must be determined whether or not the resources and personnel are available. The decision to use CAI must be made carefully since the commitment of time, funds, and personnel is so heavy and would be a great loss if the program were not successful.

CHECKLIST OF CAI REQUIREMENTS

Two checklists follow: the first covers elements essential to begin a CAI program, and without which no CAI course, regardless of how well it is done, can succeed. These items are necessary but not sufficient for success. The second covers elements which are essential to the course and along with the first group, are sufficient for success.*

ELEMENTS NECESSARY TO BEGIN A CAI PROJECT

1. Do you have the proper resources for a long-term (i.e., 5 year) project?
   - A. Funds
     - Computer ($6,500 month rental for IBM 1800 computer and peripherals with 20 percent educational discount).
     - Terminals ($7,500 month rental for 25 terminals).
     - Salaries
     - et cetera
   - B. Personnel
     - Authors
     - A–V specialist
     - Instructional programmer
     - Behavioral scientist
     - Programmers
     - et cetera
   - C. Time
     - Author (45–350 hours per instructional hour).
     - Programmer (40–555 hours per instructional hour).
2. Do you have a subject matter which is relatively stable (i.e., 3 years) which compares with the life of a textbook?
3. Do you have a large number of trainees who will be using the course (i.e., more than a one-shot course?)
4. Is this particular subject matter particularly suited to CAI (i.e., well structured, somewhat complex?
5. Do you plan on using the computer 24 hours a day? If not for instruction, then for some other function such as administration?

ELEMENTS NECESSARY FOR COURSE

1. Do you have the appropriate blocks (4 hours) of time available for the authors?
2. Do your authors have extensive teaching experience, subject matter knowledge, and an acceptance of educational technology philosophy?
3. Has the course been validated, tried out on a test group before being given for credit?
4. Do you have well-written behaviorally stated objectives?
5. Do you have precise criterion tests?
6. Do you have an efficient method of developing graphics?
7. Do you have several authors, each with a different teaching style, for each course to provide for the different learning styles of students?

*The figures cited in these checklists were obtained from U.S. Naval Academy reports.

FOOTNOTES

[1] Ross L. Morgan, *Implications of Training Research for CAI*, Proceedings from Computers in Ed., NSIA Conference (Washington, D.C.: Feb. 1970), pp. 125–126.

[2] *Ibid.*, pp. 126–127.

[3] Ray Carpenter, "Computer-Regulated Learning," in *Computers in the Classroom: An Interdisciplinary View of Trends and Alternatives* ed. by Joseph B. Margolin and Marion R. Misch (New York: Spartan Books, 1970), pp. 166–167.

[4] Felix F. Kopstein and Robert J. Seidel, *Computer-Administered Instruction Versus Traditionally Administered Instruction: Economics*, HumRRo, Professional Paper 31–67 (Washington, D.C.: Human Resources Research Organization, June 1967), p. 18.

[5] U.S. Civil Service Commission, Bureau of Training, *Programmed Instruction: A Brief of Its Development and Current Status*, Training Systems and Technology Series: No. III (Washington, D.C.: Government Printing Office, May 1970), p. 1.

[6] L. M. Stolurow, *Essential Principles of Programmed Instruction*, Tech Report No. 8, Contract Nonr 3985(04) (Urbana, Ill.: University of Illinois, Training Research Laboratory, June 1965), p. 5.

[7] IBM, *A Feasibility Study of Computer Assisted Instruction in U.S. Army Basic Electronics Training*, prepared for U.S. Continental Army Command, Contract NR DAAB 07–67–C–0578 (Fort Monroe, Va.: U.S. Continental Army Command, February 1968), pp. 4–13.

[8] *Ibid.*, p. vii.

[9] Alexander A. Longo, *The Implementation of CAI in U.S. Army Basic Electronics Training*, Tech Report 69–1 (Fort Monmouth, N.J.: U.S. Army Signal Center and School, September 1969), p. v.

[10] Kopstein and Seidel, *op. cit.*, p. 19.

[11] Elizabeth Wilson, "The Knowledge Machine," in *Computers in the Classroom* Margolin & Misch, p. 253.

[12] Robert McClintock, "Machines and Vitalists: Reflections on the Ideology of Cybernetics," *American Scholar*, Spring 1966, vol. 35, No. 2, p. 254.

[13] Jesse L. Koontz, Director Educational and Management Systems Center, U.S. Naval Academy, Annapolis, Md., personal communication.

[14] Wesley C. Meierhenry, "Computers in Education," in *Computers in the Classroom* Margolin & Misch, p. 157.

[15] IBM, *op. cit.*, pp. 4–36.

[16] IBM, *op. cit.*, pp. C–1—C–27.

[17] Charles B. Thomsen, "Computer-Aided Instruction," in *Computers in the Classroom* Margolin & Misch, p. 240.

[18] IBM, *op. cit.*, p. C–29.

[19] Kopstein and Seidel, *op. cit.*, p. 3.

[20] Robert J. Seidel and Felix F. Kopstein, *Resource Allocations to Effect Operationally Useful CAI*, HumRRO, Professional Paper 12–70 (Washington, D.C.: Human Resources Research Organization, April 1970), p. 5.

[21] U.S. Civil Service Commission, *op. cit.*, p. 5.

[22] U.S. Civil Service Commission, *op. cit.*, p. 6.

[23] U.S. Civil Service Commission, *op. cit.*, p. 7.

[24] *Idem.*

[25] Jack E. Gillikin, *Progress Report on CAI–1500 Course Development*, No. PR–0869–25 (Annapolis, Md.: U.S. Naval Academy, September 1969), p. 1.

[26] *Ibid.*, p. 4.

[27] Jack E. Gillikin, *The Naval Academy's Evaluation Design for the CAI–1500 Project*, No. PP–0869–26 (Annapolis, Md.: U.S. Naval Academy, November 1969) appendix K.

[28] *Ibid.*, p. 9.

[29] Jesse L. Koontz, personal communication.

[30] Jack E. Gillikin, *Progress Report on CAI–1500, loc. cit.*, p. 32.

[31] Jesse L. Koontz, personal communication.

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